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A COMPARISON OF THE SAOC WITH THE AGK3 CLASSICAL ANALYSIS.(U)

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A Comparison of the SAOC with the AGK3 Classical Analysis

25 February 1981

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Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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FOR THE COMMANDER

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A COMPARISON OF THE SAOC WITH THE AGK3 CLASSICAL ANALYSIS

L.G. TAFF
S.A. STANSFIELD
Group 94

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ABSTRACT

This Report discusses the systematic differences, in position and proper motion, between the Smithsonian Astrophysical Observatory Star Catalog (the SAOC) and the third Catalog der Astronomischen Gesellschaft (the AGK3). Stars in common to both catalogs, with matching BD numbers, and a positional (proper motion) difference of at most $2''.5$ ($2''.5$/cent) provide the raw data. There are 128,631 (89,709) such stars north of declination $-2^\circ.5$. The systematic differences have been examined for dependence on apparent magnitude and color index effects in addition to those depending upon position. A variety of tables and graphs illustrate the nature of the systematic differences. The mean and standard deviations in the total positional (proper motion) difference between the two catalogs are $0''.47$ and $0''.30$ ($1''.42$/cent and $0''.61$/cent). The development of the systematic differences in a complete set of orthonormal basis functions will be published separately. Approximately 1% of the stars in common to the SAOC and AGK3, identified by BD number, have a positional difference in excess of 10". Finally, there is a definite excess of positive values of $\Delta\delta$; for the 127,637 matches with $|\Delta\alpha\cos\delta| \leq 1''.25$ the mean value of $\Delta\alpha\cos\delta$ is $0''.007$ and for the 128,084 matches with $|\Delta\delta| \leq 1''.25$ the mean of value of $\Delta\delta$ is $0''.041$.

CONTENTS

I. INTRODUCTION

A classical problem in astrometry has been the evaluation of the systematic differences of the positions and proper motions in different star catalogs. Such investigations are important because they can reveal both small systematic differences in data reduction, observing technique, etc., and mistakes such as digit transposition, star mis-identifications, etc. Until very recently such investigations have been severely limited in scope because of the tremendous computational load involved. Such considerations are rapidly diminishing in importance as computing power increases and the availability of machine readable catalogs improves. This Report compares two very large star catalogs; the smaller contains 183,145 stars and the larger has 258,997 entries.

The standard method of comparing two catalogs has been to evaluate the average value of (say) a coordinate difference in relatively large, mutually exclusive, areas of the celestial sphere. After tabulating these means a smooth interpolating curve would then be used for further work. We too have constructed such values by using bin sizes of $15^m \times 2.^{\circ}5$, $30^m \times 5^{\circ}$ and $1^h \times 10^{\circ}$. Such small grids should allow us to more clearly see meaningful patterns in the differences* rather than rediscovering the fact

*We speak of differences rather than errors because the term error implies that one knows which of the positions or proper motions is correct. This is definitely not the case (indeed neither are likely to be perfect) and differences is a much better term than is errors.

that one of our catalogs is a compilation of zone catalogs (i.e., the SAOC).

A newer and more objective method of analysis was introduced by Brosche[1,2]. He suggested expanding the differences into a complete set of orthonormal basis functions and examining the properties of the expansion coefficients by statistical criteria to determine significance. The very large number of stars we have to deal with has caused us to modify the details of Brosche's approach and these results will be presented separately.

The larger star catalog is the Smithsonian Astrophysical Observatory Star Catalog[3] (the SAOC hereinafter). The smaller, but denser one, is the third of the Catalog der Astronomischen Gesellschaft[4] (the AGK3 hereinafter). The SAOC is the reference catalog for the Ground-based Electro-Optical Deep Space Surveillance (GEODSS) program: GEODSS will supplant the Baker-Nunn photographic camera system for artificial satellite tracking. The SAOC was created to be the reference catalog of the Baker-Nunn network. Hence, our primary aim is to evaluate the SAOC. To do this one needs a comparable but independent catalog. None exists, the AGK3 coming closest in this regard but only north of $\delta = -2\overset{\circ}{.}5$. In addition to finding the gross errors in the SAOC the astronomical importance of the SAOC dictates that we make an effort to discover as much as possible about its errors. Hence we have pushed the analysis somewhat beyond that required to locate stars whose position is suspect.

As many of our readers may not be well versed in the intricacies of astrometry a few words of elucidation on the exact meaning of "systematic difference" may be appropriate. For each star in the SAOC one will find a position (right ascension and declination) and a pair of proper motions (the time rates of change of right ascension and declination due to the intrinsic motion of the star). Both the position (α, δ) and the proper motions (μ_α, μ_δ) are relative to a particular coordinate system and at a particular instant of time. As astronomers use non-inertial reference frames for cataloging stellar positions the specification of an epoch of orientation for the coordinate system is crucial. Clearly, since the stars are in motion relative to an inertial reference system, the specification of an epoch of place for the star is necessary too. For every star in the SAOC these epochs are both 1950.0 (exactly when 1950.0 was is unimportant for now - the decimal notation defines a precise instant of time near January 1, 1950 which one can calculate).

For each star in the AGK3 one will also find a position and proper motions. The problem is that this data isn't the same. As an example consider the first star in the AGK3 that is also in the SAOC. It is BD +88 0001 whose 1950.0 SAOC values are

$$\alpha = 0^h15^m11\overset{s}{.}281 \qquad \mu_\alpha = +0\overset{s}{.}0979/yr$$

$$\delta = +89°23'18\overset{''}{.}32 \qquad \mu_\delta = -0\overset{''}{.}037/yr$$

and whose 1950.0 AGK3 values are

$$\alpha = 0^h 15^m 10\overset{s}{.}180 \qquad \mu_\alpha = +0\overset{s}{.}1676/\text{hr}$$

$$\delta = +89°23'18\overset{''}{.}13 \qquad \mu_\delta = -0\overset{''}{.}036/\text{yr}$$

Obviously none of these quantities agree; the positional difference is $0\overset{''}{.}26$ and the difference in proper motion is $1\overset{''}{.}12$/cent. Hence the six quantities we shall investigate are

$$\Delta\alpha\cos\delta = (\alpha_{AGK3} - \alpha_{SAOC})\cos\delta_{SAOC}$$

$$\Delta\delta = \delta_{AGK3} - \delta_{SAOC}$$

$$\Delta p = [(\Delta\alpha\cos\delta)^2 + (\Delta\delta)^2]^{1/2}$$

and $\Delta\mu_\alpha\cos\delta$, $\Delta\mu_\delta$, $\Delta\mu = [(\Delta\mu_\alpha\cos\delta)^2 + (\Delta\mu_\delta)^2]^{1/2}$ similarly defined. These quantities we expect to depend on position. They will probably also vary with the brightness of a star and its temperature. Thus we consider apparent magnitude and color index dependencies too (see Section V).

II. THE CATALOGS

As mentioned above the principal information in the SAOC for each star is α, δ, μ_α, and μ_δ all for the equator and equinox of 1950.0. Other pertinent information includes the SAOC identification number, the BD number (from Argelander's Bonner Durchmusterung whose epoch is 1855.0), the spectral type, the apparent visual magnitude (m_v), and the apparent photographic magnitude (m_{pg}). The apparent photographic magnitude is available for $\sim$50% of the stars and the spectral type is present for $\sim$83%. Both the BD number and m_v are present for $\sim$99% of the entries. There is no homogeniety in the SAOC magnitudes.

In the AGK3 we too find α, δ, μ_α, and μ_δ for epoch of orientation 1950.0 but for an epoch of place t_{ep} which varies from star to star. This time is $\sim$8 years later than 1950.0 and is separately given for each star. The AGK3 also contains AGK3 identification number, the BD number, the spectral type, and the apparent photographic magnitude. As the latter are much more homogeneous than the SAOC values, when we come to investigate magnitude effects we'll use these.

The SAOC is an all-sky catalog with at least four stars per square degree. The AGK3 is of higher density but only extends southward to $\delta = -2^\circ\!.5$. This is especially unfortunate because the SAOC is poorest in the Southern hemisphere. Also, for most Northern hemisphere locations, near-stationary artificial satellites will be primarily seen against SAOC stars and not against AGK3 stars.

The fact that the epoch of place of an AGK3 star varies means that we must either backdate an AGK3 position from t_{ep} to 1950.0 or update an SAOC position from 1950.0 to t_{ep}. The latter gives non-coeval systematic differences, hence the former is preferred. The formulas to do this are[5]

$$\alpha(1950.0) = \alpha(t_{ep}) + \mu_\alpha t + \dot{\mu}_\alpha t^2/2$$

$$\mu_\alpha(1950.0 = \mu_\alpha(t_{ep}) + \dot{\mu}_\alpha t$$

where $t = 1950.0 - t_{ep}$ and

$$\dot{\mu}_\alpha = 2\mu_\alpha \mu_\delta \tan\delta.$$

Similar equations hold for δ and μ_δ with

$$\dot{\mu}_\delta = -\mu_\alpha^2 \sin\delta\cos\delta.$$

The last point is that, independent of references 3 and 4, the versions of the catalogs we have were obtained on magnetic tape from the U.S. Naval Observatory. In particular we have the Heidelberg 1975 version of the AGK3.

III. POSITION INDEPENDENT ANALYSIS

As the purpose of this analysis is to discover positional differences between the catalogs, it seemed inadvisable to use positional coincidence (within some upper tolerance) as a means of identification. Instead, when it is present, we have chosen to use the Bonner Durchmusterung number. This eliminates less than 1% of the potential contributors to the analysis (of the 133,023 stars in the SAOC north of $\delta = -2^\circ\!.5$, 132,126 have BD numbers). Unfortunately BD numbers aren't unique due to errors and double star systems. The latter can be automatically handled (for long period binaries) if one matches BD number according to right ascension. Lastly, even if the BD numbers match, when the positional difference is too large we're more apt to declare a mistake of some sort rather than a true systematic difference. Of course no matter what level we choose to separate "real difference" from "mistake" we shall always have some of each in both categories. We're conservative and we use $\Delta p = 2''\!.5$ as the dividing line for further work.

A. Positions

A simple thing that we can do is tabulate the number of BD matching stars in both catalogs that have values of $\Delta\alpha\cos\delta$ in a certain range, values of $\Delta\delta$ in a certain range, or values of Δp in a certain range. The cores of the component distributions are shown in Figure 1 using $0''\!.05$ for a bin size. One's

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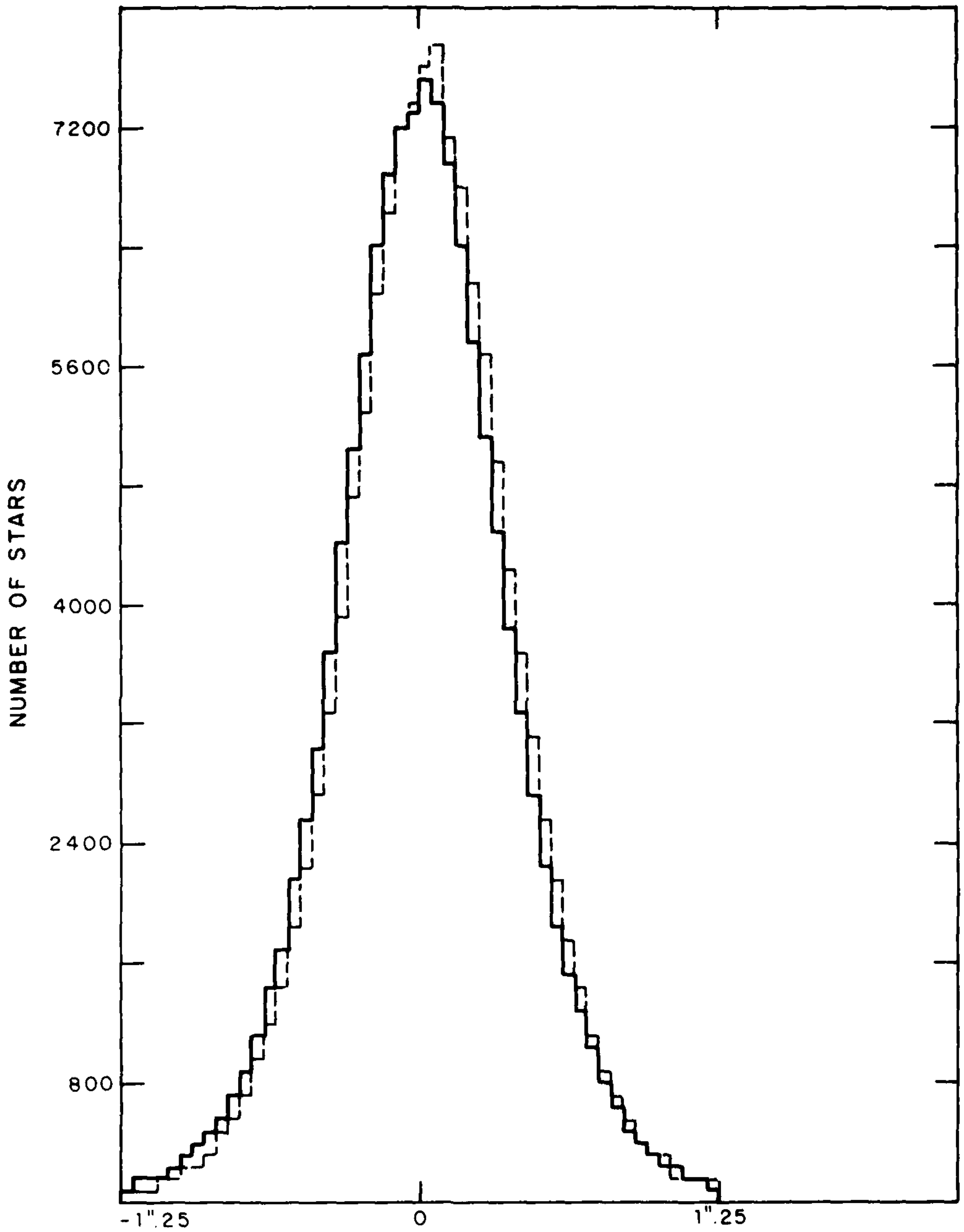

Fig.1. The distributions of $\Delta\alpha\cos\delta$ (solid) and $\Delta\delta$ (dotted).

visual impression is that the widths of the $\Delta\alpha\cos\delta$ and $\Delta\delta$ distributions are equal and that there is a definite excess of positive $\Delta\delta$ values. For the 127,637 matches with $|\Delta\alpha\cos\delta| \leq 1''.25$ the mean value of $\Delta\alpha\cos\delta$ is $0''.007$ and the standard deviation about the mean is $0''.374$ (the standard error of the mean is $0''.001$). For $|\Delta\delta| \leq 1''.25$ the corresponding values are 128,084, $0''.041$, and $0''.367$ (with the standard error of the mean $0''.001$ again). Hence our eyes haven't deceived us. Table 1 lists the actual numbers. Out of 130,065 matches north of $\delta = -2^\circ.5$, 1,044 have $|\Delta\alpha\cos\delta|$ in excess of 5" while 1,029 have $|\Delta\delta| > 5''$.

Were the $\Delta\alpha\cos\delta$ and $\Delta\delta$ distributions normal with zero means and equal variances (say σ^2) then the frequency function for $\Delta p = [(\Delta\alpha\cos\delta)^2 + (\Delta\delta)^2]^{1/2}$ would be a Rayleigh distribution,

$$P(\Delta p) = \frac{\Delta p}{\sigma^2} \exp\left[-\frac{(\Delta p)^2}{2\sigma^2}\right]$$

In fact, using the maximum likelihood estimator for σ^2 ($= 0''.141$ for the 127,554 stars with $\Delta p \leq 1''.5$), a reasonable approximation to the Δp distribution shown in Figure 2 can be obtained. (The tabular values of the Δp distribution are given in Table 1; 1,067 stars have Δp in excess of 10"). The fact that the $\Delta\delta$ distribution clearly has a non-zero mean implies that a better approximation would be given by the equation on page 13.

TABLE 1

NUMBERS OF SYSTEMATIC POSITIONAL DIFFERENCES

	$\Delta\alpha\cos\delta$	$\Delta\delta$		Δp
-1″25:-1″20	105	73	0″00: 0″05	1495
-1.20:-1.15	135	92	0.05: 0.10	4268
-1.15:-1.10	144	114	0.10: 0.15	6696
-1.10:-1.05	197	134	0.15: 0.20	8556
-1.05:-1.00	232	192	0.20: 0.25	9631
-1.00:-0.95	281	223	0.25: 0.30	10382
-0.95:-0.90	389	249	0.30: 0.35	10532
-0.90:-0.85	465	355	0.35: 0.40	10327
-0.85:-0.80	572	471	0:40: 0.45	9462
-0.80:-0.75	717	593	0.45: 0.50	8775
-0.75:-0.70	918	734	0.50: 0.55	7688
-0.70:-0.65	1140	979	0.55: 0.60	6840
-0.65:-0.60	1467	1183	0.60: 0.65	5925
-0.60:-0.55	1717	1465	0.65: 0.70	4870
-0.55:-0.50	2194	1809	0.70: 0.75	4187
-0.50:-0.45	2573	2227	0.75: 0.80	3434
-0.45:-0.40	3075	2707	0.80: 0.85	2924
-0.40:-0.35	3678	3251	0.85: 0.90	2246
-0.35:-0.30	4421	3936	0.90: 0.95	1894
-0.30:-0.25	5078	4696	0.95: 1.00	1544
-0.25:-0.20	5655	5286	1.00: 1.05	1272
-0.20:-0.15	6365	6073	1.05: 1.10	1014
-0.15:-0.10	6859	6630	1.10: 1.15	887
-0.10:-0.05	7215	7185	1.15: 1.20	674
-0.05: 0.00	7289	7397	1.20: 1.25	535
0.00: 0.05	7488	7569	1.25: 1.30	418
0.05: 0.10	7349	7734	1.30: 1.35	351
0.10: 0.15	6946	7102	1.35: 1.40	299
0.15: 0.20	6366	6822	1.40: 1.45	233
0.20: 0.25	5755	6151	1.45: 1.50	195
0.25: 0.30	5117	5650	1.50: 1.55	179
0.30: 0.35	4516	4985	1.55: 1.60	141
0.35: 0.40	3857	4277	1.60: 1.65	91
0.40: 0.45	3316	3684	1.65: 1.70	90
0.45: 0.50	2711	3148	1.70: 1.75	94
0.50: 0.55	2202	2595	1.75: 1.80	64
0.55: 0.60	1813	2124	1.80: 1.85	57
0.60: 0.65	1517	1783	1.85: 1.90	49
0.65: 0.70	1258	1443	1.90: 1.95	52
0.70: 0.75	1001	1135	1.95: 2.00	41
0.75: 0.80	763	908	2.00: 2.05	52
0.80: 0.85	648	697	2.05: 2.10	24
0.85: 0.90	485	533	2.10: 2.15	20
0.90: 0.95	416	426	2.15: 2.20	20

TABLE 1 (continued)

0.95: 1.00	352	355	2.20: 2.25	18
1.00: 1.05	255	284	2.25: 2.30	16
1.05: 1.10	211	196	2.30: 2.35	22
1.10: 1.15	175	181	2.35: 2.40	16
1.15: 1.20	141	126	2.40: 2.45	15
1.20: 1.25	98	122	2.45: 2.50	16

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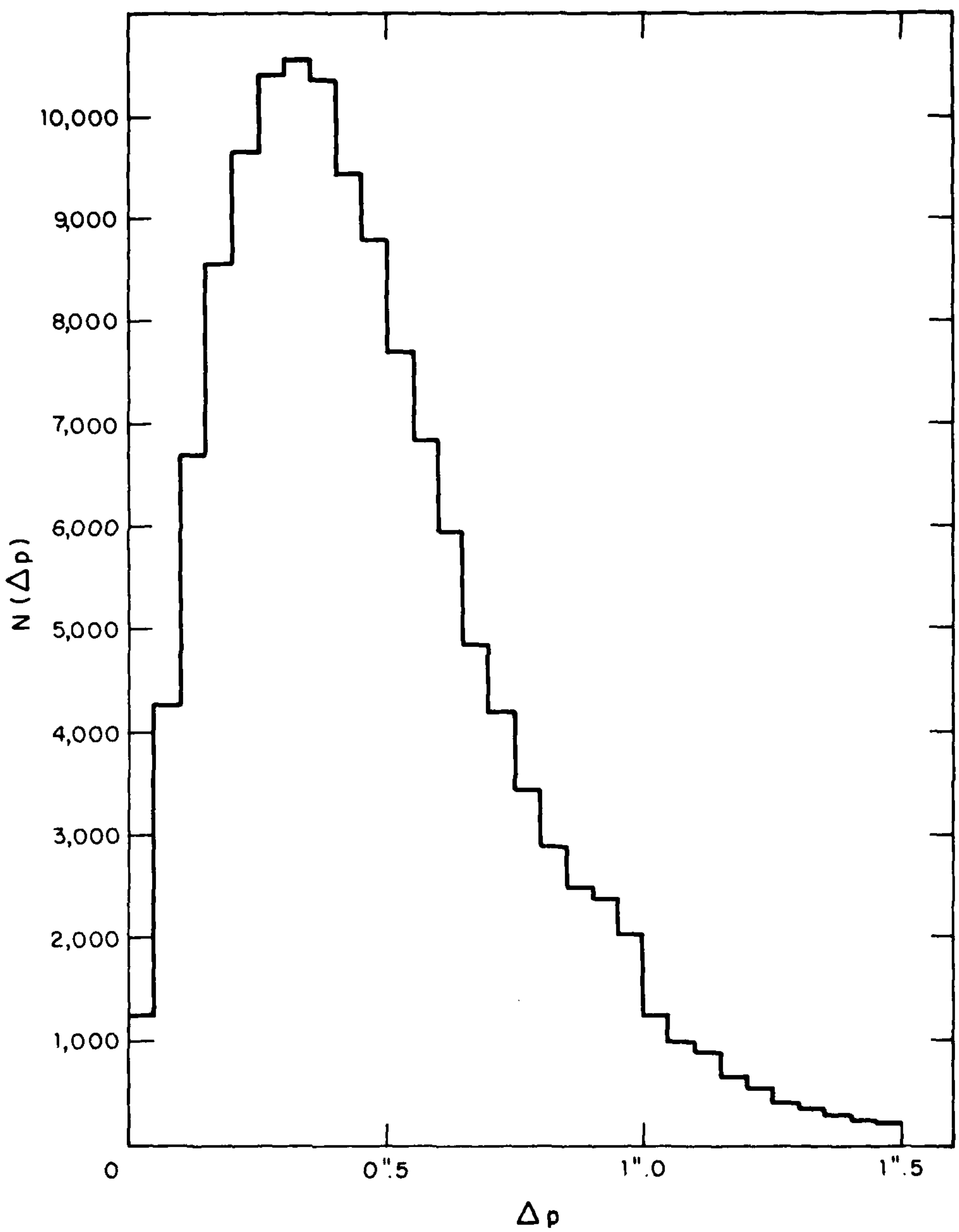

Fig.2. The distribution of Δp.

$$P(\Delta p) = \frac{\Delta p}{\sigma^2} I_0 \left(\frac{\mu \Delta p}{\sigma^2}\right) \exp\left[- \frac{(\Delta p)^2 + \mu^2}{2\sigma^2}\right]$$

which is the distribution for $\Delta p = (x^2 + y^2)^{1/2}$ when x and y are independently normally distributed with the common variance σ^2 but x has a mean of zero and y has a mean of μ. As I_o (0) - I_o is the modified Bessel function of order zero - is unity, the above Rayleigh distribution is clearly a special case of this one. The presence of the Bessel function makes the computation of maximum likelihood estimators for μ and σ tiresome and this hasn't been done.

Lastly, as we increase the upper limit on Δp for inclusion from 2".5 to 5".0 and then 10" the number of successfully matching stars changes from 128,631 to 128,819 and then to 128,998 while the mean and standard deviation of the distribution goes from 0".469 and 0".296 to 0".473 and 0".316 and then to 0".483 and 0".419.

B. Proper Motions

Proceeding in an exactly analogous fashion, we can construct the $\Delta\mu_\alpha \cos\delta$, $\Delta\mu_\delta$, and $\Delta\mu = \left[(\Delta\mu_\alpha \cos\delta)^2 + (\Delta\mu_\delta)^2\right]^{1/2}$ histograms. The immediate thing one notices is that the proper motion distributions are much broader than are the positional distributions (see Figures 3 and 4).

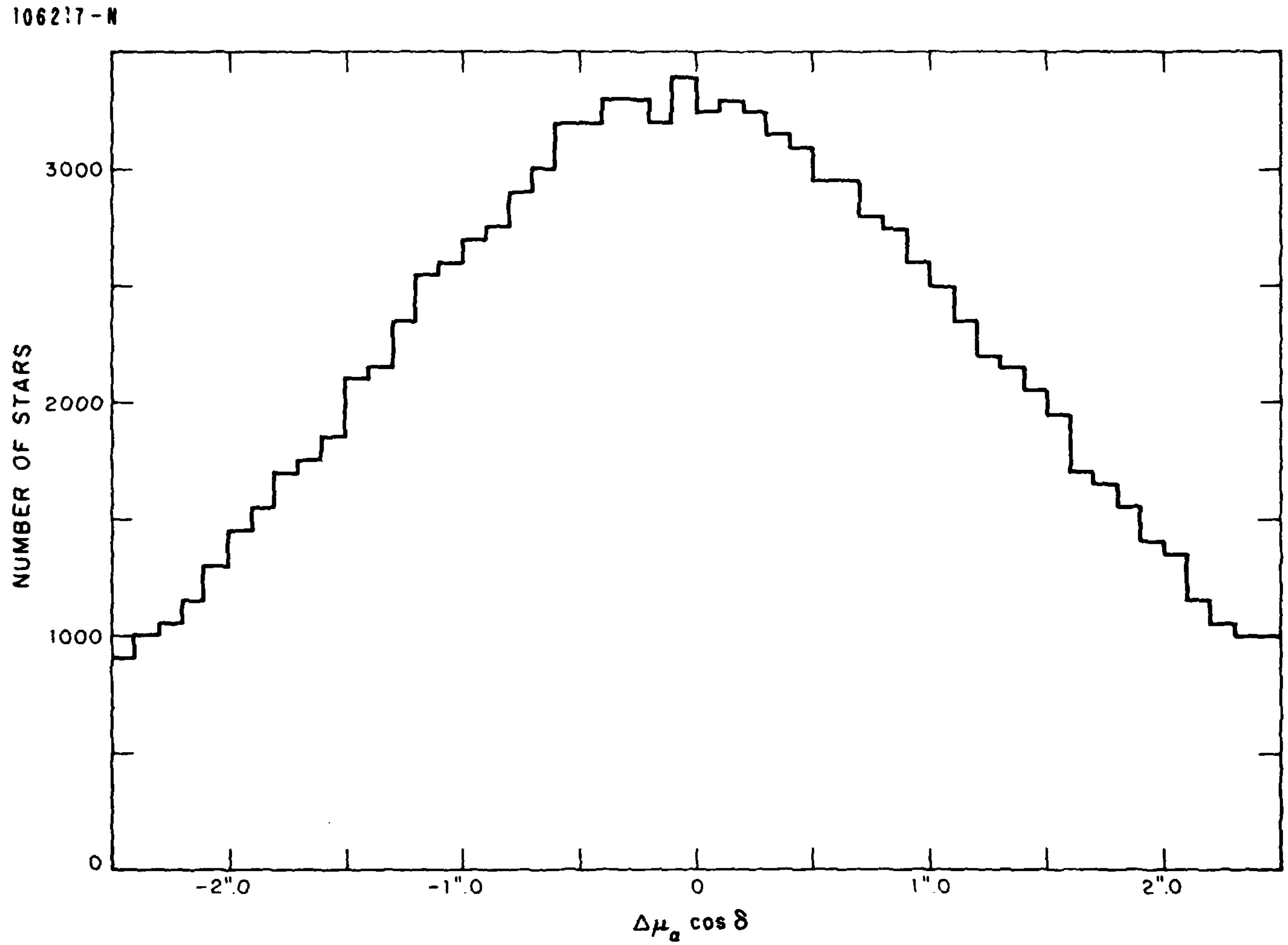

Fig.3a. The distribution $\Delta\mu_{\alpha}\cos\delta$. Note the width.

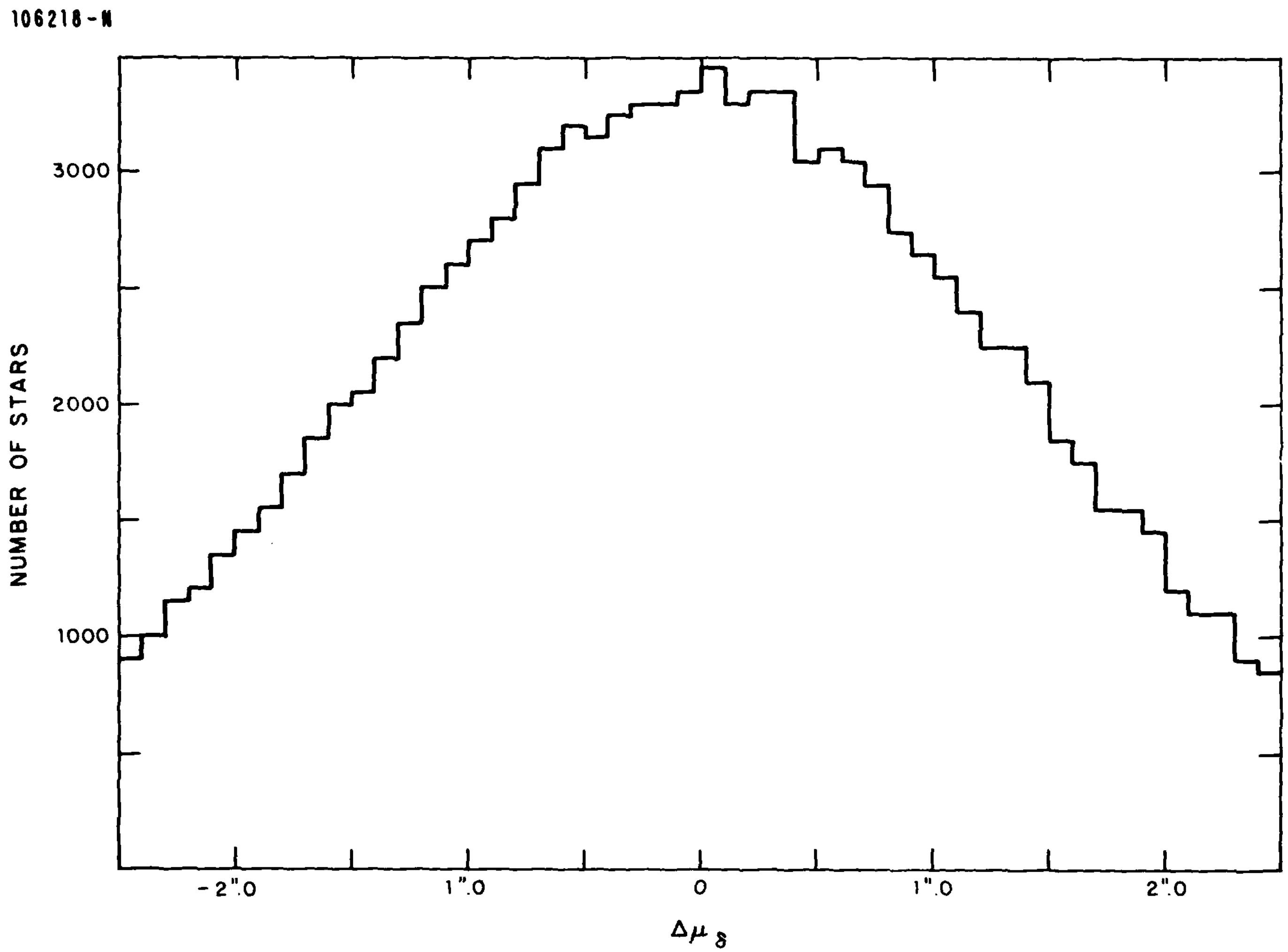

Fig.3b. The distribution of $\Delta\mu_\delta$. Note the width.

There are only 89,709 stars with $\Delta\mu \leq 2''.5$/cent, but 126,071 up to $5''.0$/cent, and 129,744 bounded above by 10"/cent. The corresponding means and standard deviations are $1''.42$/cent and $0''.606$/cent; $1''.97$/cent and $1''.06$/cent; and $2''.08$/cent and $1''.25$/cent. Figures 3a and 3b show the $\Delta\mu_\alpha\cos\delta$ and $\Delta\mu_\delta$ distributions within $2''.5$/cent of zero in $0''.1$/cent bin sizes. Figure 4 contains the $\Delta\mu$ distribution out to $3''.5$/cent in $0''.05$/cent bins. Visually, unlike the case for the positions, there is no obvious difference between the distribution of the systematic differences in proper motion in right ascension along a great circle and the distribution of the systematic differences in proper motion in declination. The systematic differences for 113,986 stars are contained in the $\Delta\mu_\alpha\cos\delta$ plot, 112,993 in the $\Delta\mu_\delta$ plot, and 113,611 in the $\Delta\mu$ plot. In this case, a Rayleigh distribution is a reasonable approximation to the innermost $2''.0$/cent of the $\Delta\mu$ distribution. Finally, 1696 stars had a $|\Delta\mu_\alpha\cos\delta| > 5''$/cent, 1237 had a $|\Delta\mu_\delta| > 5''$/cent, but only 321 had a $\Delta\mu > 10''$/cent.

This brief survey has shown us two unexpected facts. First is the excess number of positive values for $\Delta\delta$. We shall see another representation of this below. One naively expects the $\Delta\alpha\cos\delta$ and $\Delta\delta$ (and the $\Delta\mu_\alpha\cos\delta$ and $\Delta\mu_\delta$) distributions will be nearly identical - in fact, nearly normal with zero means. The second unexpected result is that ~1% of the stars, presumably positively identified, have excessively large positional

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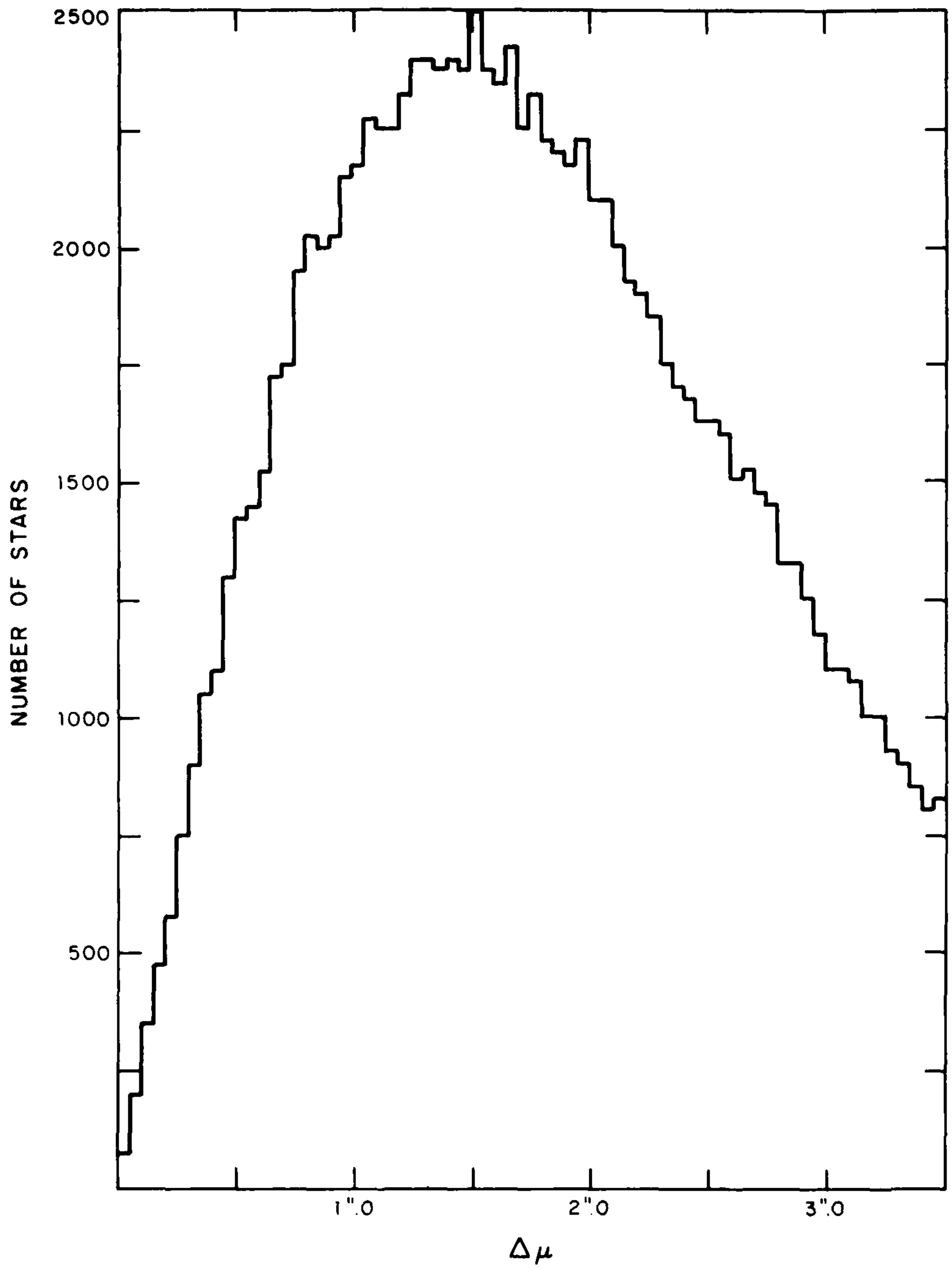

Fig.4. The distribution of Δμ.

differences. It is our hope that the source of these discrepancies can ultimately be tracked down. Until then, Table 2 lists the SAOC identification number and value of Δp (to the nearest tenth of a minute of arc) for all of the stars in both the AGK3 and SAOC, as identified by BD number, for which $\Delta p \geq 6''$. Obviously we cannot tell at this stage which catalog is in error (here undoubtedly the appropriate term).

TABLE 2

SAOC ID NUMBERS FOR STARS WITH Δp ≥ 0″.1

SAOC #	Δp	SAOC #	Δp	SAOC #	Δp	SAOC #	Δp
11	0″.6	596	0″.4	930	0″.8	1065	1″.5
1165	2.1	1263	0.2	1384	2.4	1702	0.2
1824	0.1	2320	0.7	2341	1.4	2404	0.1
2592	2.6	2626	1.3	2818	0.4	2826	1.9
3466	2.8	3842	1.1	4092	0.6	4147	2.7
4262	1.2	4261	1.3	4335	0.8	4394	1.4
4434	1.4	4435	0.2	4465	0.8	4508	1.0
4636	0.3	4545	1.2	4743	1.4	4776	0.7
4824	1.0	4894	0.4	5023	0.5	5133	1.6
5410	0.2	5427	0.2	5447	0.9	5515	5.8
5682	2.6	6140	4.0	6157	1.9	6279	3.6
6331	4.2	6341	1.2	6433	1.1	6461	0.5
6542	0.2	6544	1.2	6668	2.0	6899	0.9
7032	0.1	7064	0.1	7065	0.1	7431	1.0
7623	0.5	7730	2.0	7835	3.3	7967	1.5
8085	1.3	8267	1.2	8383	0.4	8465	0.2
8601	2.0	8687	0.1	8738	1.2	8999	0.4
9014	0.8	9533	2.6	9570	0.1	9807	0.3
9154	2.6	9949	3.1	9991	2.2	10163	1.3
10172	1.2	10264	0.5	10318	3.9	10324	1.9
10533	4.3	10559	2.4	10644	1.2	10681	1.5
10711	0.4	10725	1.4	10726	0.1	10728	3.2
10817	2.3	10906	1.3	10915	1.2	10991	0.6
11001	11.1	11055	1.2	11109	0.6	11199	1.1
11257	0.5	11261	0.3	11448	0.4	11454	0.1
11760	0.8	11835	0.1	11926	4.0	12020	0.1
12021	0.8	12040	1.4	12075	0.6	12176	0.8
12222	1.4	12363	0.1	12560	0.2	12635	0.1
12690	0.8	12920	0.4	13020	2.2	13022	0.7
13172	0.6	13305	0.7	13563	1.3	13601	3.7
13973	15.0	14037	0.5	14169	1.1	14202	0.1
14363	0.7	14436	1.4	14473	0.6	14638	0.5
14648	0.2	14823	0.9	14869	1.0	14908	0.4
15097	57.7	15143	0.3	15396	0.1	16270	1.3
16326	1.3	16332	1.1	16478	0.2	16904	0.7
17063	0.1	17161	0.7	17176	0.1	17589	64.6
17591	0.5	17717	0.4	17764	1.1	17882	0.8
17963	0.3	18251	0.8	18290	0.2	18326	1.1
18378	0.9	18578	0.7	18678	0.2	18704	1.6
18844	0.2	19124	1.4	19131	1.0	19177	0.8
19187	0.8	19138	0.1	19240	0.8	19346	2.3
19417	1.4	19558	0.1	19731	1.4	19754	3.2
19783	0.2	19649	1.0	19899	0.1	19922	0.3
19956	2.2	20153	1.5	20218	0.1	20219	0.1
20488	0.1	20614	1.6	20762	1.8	20922	0.6
21015	1.6	21226	0.7	21517	1.2	21610	0.5
21778	1.1	21766	0.8	21830	1.6	21864	0.6
21865	7.5	21868	5.2	21890	0.2	22042	0.8
22209	1.6	22374	0.3	22779	0.5	22814	0.2
23022	1.0	23071	0.4	23084	0.9	23309	0.4

TABLE 2 (Continued)

SAOC #	Δp	SAOC #	Δp	SAOC #	Δp	SAOC #	Δp
23331	0.1	23389	0.4	23423	0.2	23588	0.3
23764	0.3	24008	0.3	24061	5.0	24358	0.7
24543	0.6	24583	0.1	24692	0.3	24807	170.2
24835	0.3	24981	1.5	24999	0.2	25109	0.2
25133	1.3	25162	0.7	25444	1.0	25773	0.8
26240	1.3	26411	0.5	26449	1.0	26832	1.8
27250	2.0	27295	4.5	27304	0.1	27308	0.3
28290	0.2	28298	13.5	28397	1.8	28561	0.3
28637	0.8	28714	0.4	29032	0.2	29064	0.1
29108	0.7	29370	0.7	29372	0.7	29837	0.1
30517	0.8	30665	0.2	30715	0.6	30716	0.6
30728	0.2	31128	0.2	31129	0.2	31236	2.1
31512	0.3	31585	0.9	31630	1.0	32015	0.1
32043	3.2	32233	0.3	32328	2.3	32380	0.9
32481	0.5	32809	1.2	32967	3.5	33299	0.9
33547	0.3	33570	0.2	33626	0.3	33675	293.6
33747	0.4	34143	1.2	34168	1.3	34370	3.4
34565	0.7	34617	0.9	35107	0.7	35481	1.0
35596	0.9	35938	0.4	36019	0.3	36214	0.3
36228	1.6	36405	0.5	36537	0.2	36754	0.4
37071	0.8	37087	0.2	37284	0.5	37304	0.7
37460	1.6	37601	1.5	37873	0.5	37940	0.2
38125	0.1	38382	1.8	38468	0.3	38680	0.5
38748	0.8	38788	0.9	38875	0.1	39441	0.1
39500	0.2	39837	0.1	39894	0.3	40105	1.6
40226	0.2	40251	0.4	40594	0.5	40597	0.9
41544	1.7	41622	1.2	42069	0.5	42323	0.5
42336	0.5	42754	0.1	42832	0.7	42908	1.7
43533	1.4	44097	0.2	44100	1.9	44545	0.1
44617	0.3	44927	0.2	45045	0.3	45180	0.5
45248	1.4	45289	1.0	45331	1.3	45417	0.2
45423	1.2	45471	0.1	45472	0.1	45551	0.7
45616	0.6	45965	35.4	46214	20.3	46231	0.1
46440	1.7	46907	0.3	47008	1.8	47320	0.3
47475	1.2	47724	0.7	47751	0.7	47890	2.6
48112	0.9	48305	0.5	48404	1.4	48440	1.2
48652	0.7	48773	3.2	48799	1.2	48999	0.3
49020	0.2	49067	0.8	49314	1.3	49431	0.1
49691	0.1	49698	0.1	49713	0.1	49741	1.0
49774	2.3	49797	0.1	49798	0.2	49899	1.8
50021	0.1	50043	1.4	50140	0.1	50462	0.3
50520	0.2	50731	0.4	51119	0.6	51167	1.0
51402	0.7	51792	0.6	51907	0.2	51971	0.7
52155	0.7	52347	1.0	52381	0.2	52403	0.7
52514	26.8	52628	0.1	52672	254.7	52712	249.7
52778	0.7	52890	0.2	52914	1.3	52931	275.8
53051	0.2	53249	1.4	53383	0.2	53389	0.1
53393	0.2	53999	0.2	54080	1.0	54184	0.2
54224	1.2	54421	0.9	54513	0.3	55038	0.7
55190	0.5	55285	1.1	55321	0.2	55322	0.2
55424	0.7	55425	0.2	55687	0.2	55730	0.2

TABLE 2 (Continued)

SAOC #	Δp	SAOC #	Δp	SAOC #	Δp	SAOC #	Δp
55767	0.5	55862	0.1	55883	2.7	55941	0.1
55975	0.2	56292	0.8	56353	0.4	56495	1.3
56623	0.3	56733	4.6	56734	0.8	56902	0.4
56953	0.8	56987	0.2	57078	0.9	57873	0.3
58006	0.2	58086	0.3	58280	0.2	58305	0.7
58800	0.4	59523	2.0	59684	0.1	59847	0.7
59962	0.3	60353	1.0	60396	1.5	60603	0.3
60635	1.5	60691	1.3	60916	1.0	60973	0.2
61080	0.2	61163	2.8	61531	0.8	62068	0.2
62316	1.9	62400	1.1	62571	1.7	62892	2.3
63171	0.2	63375	0.1	63446	0.5	63654	0.9
63665	0.1	63809	0.8	63960	0.2	64206	0.3
64260	1.8	64300	0.2	64464	0.4	64756	1.1
64811	1.9	64983	0.2	65276	0.1	65322	0.4
65937	0.9	66535	0.3	66546	0.6	66623	0.7
67107	2.1	67174	1.1	67250	0.2	67286	0.2
67422	0.2	67443	0.6	67543	3.4	67605	1.0
67608	1.2	67648	0.2	67730	1.6	68022	0.5
68150	0.2	68216	2.2	68297	0.2	68497	0.4
68510	1.8	68672	0.7	68796	1.1	68974	0.2
69023	1.6	69162	0.3	69300	0.9	69333	17.1
69402	0.2	69856	1.3	70167	0.1	70203	2.0
70220	0.4	70230	0.4	70321	0.7	70915	0.3
70916	0.6	70919	0.2	71158	0.3	71294	0.7
71434	1.3	71536	1.0	71645	0.5	71746	0.8
71753	0.3	71921	0.5	72018	0.4	72086	1.9
72088	0.2	72187	0.1	72228	0.3	72247	0.2
72329	1.0	72475	0.1	72501	0.7	72563	0.7
72575	1.0	72808	0.4	72884	0.3	72939	0.9
73398	0.3	73578	0.3	73704	0.2	73757	1.3
73765	1.4	73823	0.3	73877	1.3	73934	0.4
73969	1.1	73973	1.5	74071	0.2	74160	1.0
74338	0.2	74463	1.5	74477	0.2	74962	0.3
74981	0.4	75242	2.0	75304	0.2	75305	0.2
75658	174.3	75882	0.9	76086	1.2	76297	1.0
76338	1.0	76430	2.3	76880	0.3	76943	2.9
76989	1.2	76991	0.2	77122	0.1	77210	0.2
77353	0.1	77422	1.3	77478	0.2	77523	0.2
77539	3.1	77894	0.2	78022	1.0	78038	0.5
78543	0.2	79337	1.3	79387	1.3	79401	0.6
79703	1.5	79773	0.2	79785	1.7	79845	33.7
80198	0.2	80328	1.3	80505	0.9	80586	0.2
80680	1.1	81299	32.4	81364	0.1	81420	0.2
81837	0.7	82462	0.1	82553	37.8	82877	0.2
82901	0.8	83300	0.1	83458	1.2	83673	0.3
83768	2.4	83685	0.1	84018	0.2	84059	0.4
84157	1.0	84214	1.4	84356	1.4	84682	1.7
84897	0.6	84908	0.2	85031	0.1	85145	1.2
85222	1.3	85397	0.6	85471	3.0	85569	0.1
85589	0.3	85793	1.6	86223	0.2	86293	0.7
86437	0.3	86538	2.0	86774	0.2	86828	0.2

TABLE 2 (Continued)

SAOC #	Δp	SAOC #	Δp	SAOC #	Δp	SAOC #	Δp
86834	0.2	86972	3.2	87005	0.8	87094	1.3
87126	1.8	87407	1.4	87662	0.1	87684	2.2
87736	0.9	87790	1.2	87802	0.2	88010	1569.6
88069	1.2	88084	2.9	88153	1.7	88415	0.3
88457	0.6	88498	2.9	88793	1.1	88817	1.3
88901	0.5	88967	0.2	88995	1.9	89136	0.4
89501	1.3	89628	1.1	89872	0.1	89914	1.5
90063	1.0	90093	1.1	90222	0.1	90349	0.4
90366	1.8	90464	0.2	90839	0.2	90865	0.3
90873	1.4	91022	0.9	91032	0.3	91149	0.4
91264	0.8	91409	0.6	91595	1.0	91615	0.6
91616	0.2	91819	0.2	91822	5.0	91866	0.5
91903	1.8	91950	0.5	92005	1.1	92157	0.5
92202	0.1	92316	1439.9	92375	0.5	92464	1.7
92468	0.2	92477	1.6	92492	0.8	92705	0.5
92827	0.7	92893	1.0	93021	1.0	93110	0.4
93165	0.2	93244	0.3	93284	1.8	93479	0.3
93488	1.2	93842	0.1	94033	1.3	94133	0.4
94376	0.9	94430	0.4	94729	0.1	94746	0.2
94762	2.0	94818	2.5	94935	0.6	95002	0.7
95004	0.7	95215	0.6	95234	0.4	95269	1.1
95273	0.9	95438	1.1	95510	15.1	96505	0.2
96547	0.1	96663	48.9	96728	0.2	96655	0.3
96892	0.2	96898	0.3	96965	0.2	97005	0.8
97065	1.4	97334	1.0	97411	0.2	97434	0.6
97584	1.0	97599	0.8	97672	35.8	98097	0.4
98219	1.9	98249	0.1	98595	0.8	98766	1.4
98795	0.2	98796	0.2	98816	1.7	98845	1.5
98977	0.2	99057	0.2	99067	0.7	99162	0.8
99168	1.8	99184	0.1	99212	0.4	99284	0.7
99298	0.6	99310	0.3	99378	0.3	99408	0.2
99413	0.2	99453	0.1	99479	1.0	99653	1.1
99735	0.4	99743	1.7	99765	0.1	99808	0.1
99967	1.2	100032	0.2	100071	2.4	100195	0.1
100337	0.5	100348	1.3	100366	2.4	100534	0.2
100558	0.7	101040	1.0	101583	0.3	101673	0.3
101721	0.9	101772	0.3	101831	0.8	101835	1.5
101858	0.4	101864	0.1	101992	1.0	102059	1.3
102255	1.4	102327	1.1	102558	1.0	102636	0.9
102694	1.2	102877	2.1	102896	0.3	103095	0.1
103140	0.6	103143	1.2	103167	0.2	103214	1.0
103340	0.8	103746	1.3	103872	0.3	104004	1.2
104018	0.9	104308	0.3	104332	0.3	104333	0.1
104422	0.2	104432	0.1	104490	0.2	104513	0.2
104557	0.1	104753	0.1	104785	0.5	104940	1.1
105004	1.0	105165	1.3	105193	0.3	105234	3.0
105252	0.9	105309	0.6	105423	1.4	105485	2.1
105523	1.3	105576	0.5	105634	2.1	105637	1.8
105639	0.7	105687	0.3	105690	0.7	105704	0.5
105714	0.1	105718	0.3	105728	0.3	105733	1.8
105734	1.0	105755	1.6	105758	1.1	105811	1.1

TABLE 2 (Continued)

SAOC #	Δp	SAOC #	Δp	SAOC #	Δp	SAOC #	Δp
105826	0.2	105868	1.6	105894	0.9	105906	0.7
105912	0.1	105929	1.1	105956	1.4	105958	0.8
105982	1.4	106006	0.7	106078	0.3	106079	0.3
106080	0.3	106091	0.4	106134	0.6	106181	1.3
106193	0.2	106223	0.3	106427	1.0	106430	0.1
106456	2.8	106494	1.0	106500	0.1	106542	1.7
106543	0.2	106553	1.3	106642	0.5	106719	0.2
106732	0.6	106755	0.2	106766	1.6	106781	1.5
106818	1.2	106823	0.3	106830	1.0	106833	0.5
106879	0.3	106890	1.2	106938	0.3	106947	1.4
107060	0.2	107065	1.8	107147	1.7	107165	2.3
107213	0.7	107287	0.4	107346	1.6	107352	1.0
107383	0.9	107484	1.0	107526	0.2	107539	1.4
107582	1.4	107685	0.7	107691	1.1	107830	0.8
107862	0.2	108079	0.3	108160	0.2	108286	1.2
108426	1.2	108434	0.5	108463	0.6	108513	1.2
108622	0.1	108802	1.6	108816	0.7	108856	1.0
109272	0.2	109299	0.4	109334	0.3	109459	1.4
109484	1.5	109510	0.7	109521	0.1	109573	0.3
109596	1.2	109629	0.8	109643	0.3	109780	0.5
109802	1.5	109818	1.1	109978	1.3	110002	0.6
110038	1.8	110202	1.0	110276	2.2	110355	2.3
110395	1.2	110421	0.4	110461	1.1	110515	2.8
110623	0.5	110658	1.1	110661	1.3	110720	0.5
110738	1.5	110799	0.8	110807	1.5	110849	3.2
110913	0.2	110951	0.3	110973	1.4	110995	0.3
111240	2.5	111254	0.1	111340	0.6	111466	0.2
111557	0.7	111558	2.0	111623	0.2	111659	0.2
111700	0.9	111779	0.6	111795	0.5	111804	0.6
111858	0.7	111996	0.6	112012	0.6	112054	0.8
112353	0.5	112358	1.0	112616	1.7	112620	1.3
112650	0.5	112655	1.0	112726	1.1	112842	1.3
112873	1.1	112971	0.4	113124	0.3	113129	0.9
113145	1.8	113190	0.3	113262	1.4	113408	0.3
113416	1.0	113431	1.1	113435	0.7	113438	0.6
113469	0.4	113558	0.5	113573	0.2	113645	1.0
113669	1.0	113671	0.2	113786	1.4	113802	1.2
113900	1.0	113973	0.2	113991	0.2	113996	0.6
114038	0.7	114132	0.5	114139	0.2	114146	3.4
114208	0.6	114222	0.1	114300	0.4	114303	1.5
114331	1.4	114333	1.5	114354	1.3	114373	1.4
114408	1.0	114414	0.6	114501	0.3	114529	2.6
114603	0.1	114624	0.2	114651	0.2	114689	0.6
114763	0.8	114764	1.4	114776	1.9	114795	0.4
114852	1.1	114921	0.3	114940	0.4	114972	1.6
115033	0.1	115116	0.1	115119	2.0	115172	1.0
115188	3.9	115223	0.9	115243	0.5	115259	0.7
115264	1.8	115285	0.4	115297	1.0	115328	0.5
115341	0.4	115353	0.5	115366	1.9	115467	0.9
115590	0.6	115596	0.9	115669	0.9	115685	0.2
115811	0.5	115850	1.4	115857	1.4	116008	0.9

TABLE 2 (Continued)

SAOC #	Δp	SAOC #	Δp	SAOC #	Δp	SAOC #	Δp
116018	2.3	116086	1.0	116090	0.9	116117	0.2
116369	0.1	116496	0.9	116535	0.2	116659	0.4
116696	0.2	116825	0.7	116876	1.8	116924	1.4
117128	0.7	117375	0.4	117591	1.4	117596	0.2
117604	0.5	117643	3.0	117688	1.2	117698	2.0
117792	0.1	117902	1.1	117908	1.0	118167	1.2
118299	1.9	118387	0.2	118430	2.1	118507	5.5
118548	0.2	118689	1.1	118771	0.6	118901	1.3
119042	0.2	119046	3.3	119118	0.2	119282	0.4
119284	0.5	119298	0.8	119360	0.3	119382	0.1
119399	0.9	119403	0.9	119551	0.3	119611	1.0
119680	0.1	119696	0.4	120006	0.6	120036	1.0
120154	0.6	120202	1.2	120312	0.9	120403	1.4
120426	1.0	120435	0.8	120728	1.6	120746	1.4
121056	0.1	121092	0.2	121215	1.2	121517	0.1
121667	0.1	121831	2.4	121950	50.4	122108	0.3
122235	1.8	122257	0.1	122400	0.4	122464	1.3
122616	1.7	122662	0.6	122688	0.1	122770	22.5
122764	1.2	123019	1.2	123060	1.9	123066	2.2
123086	0.1	123176	2.3	123254	1.5	123338	2.7
123428	0.2	123473	0.6	123480	0.8	123624	0.1
123786	0.4	123825	0.2	124010	0.2	124177	0.2
124289	0.5	124340	0.1	124350	0.7	124438	1.4
124440	1.8	124459	0.5	124503	1.4	124546	2.0
124606	0.7	124626	1.1	124648	1.0	124679	0.5
124778	1.0	124851	0.3	124854	0.2	124903	2.1
124918	0.6	124930	0.3	124940	3.5	124966	1.5
124969	0.4	125018	1.4	125030	0.2	125064	1.0
125126	1.1	125183	0.2	125259	0.2	125270	2.3
125380	0.2	125504	1.8	125521	0.3	125557	0.7
125610	5.3	125614	1.0	125666	0.9	125692	0.2
125702	1.6	125979	3.6	126026	2.1	126112	0.4
126346	0.1	126419	0.2	126576	0.4	126860	1.3
126914	0.9	126957	0.6	126982	0.4	127020	0.4
127121	0.1	127176	2.9	127294	7.4	127295	7.4
127339	0.2	127352	1.2	127538	1.8	127728	1.6
127770	0.3	127821	0.6	127956	0.4	127981	0.3
127982	0.3	128001	0.5	128050	1.1	128065	1.6
128078	1.5	128186	2.8	128216	0.2	128468	0.7
128506	0.4	128508	0.7	129305	1.0	129706	1.3
129898	47.6	129964	1.5	129971	0.9	130038	0.2
130205	0.2	130382	1.0	130477	0.3	131216	1.0
132131	0.9	132247	0.5	132291	0.2	132937	0.1
132959	0.1	133197	0.2	133207	1.4	133635	1.4
134005	1.3	134073	0.4	134336	1.7	135227	0.2
136375	2063.1	136476	0.4	138626	0.4	138663	23.5
139227	0.2	139231	0.3	139317	0.4	139359	2515.8
140198	2470.3	141084	0.2	141085	0.2	141806	0.2
141522	0.3	142063	0.1	143029	0.2	143378	60.0
143469	0.4	144019	2.5	145359	4.2	145626	0.6
145821	1.4	145829	4.1	146094	0.1	146604	0.8

IV. VARIATIONS OVER THE HEMISPHERE

The mean values of $\Delta\alpha\cos\delta$, $\Delta\delta$, Δp, $\Delta\mu_{\alpha}\cos\delta$, $\Delta\mu_{\delta}$, and $\Delta\mu$ have been computed across the northern celestial hemisphere in bins of sizes 1^{h}x10°, 30^{m}x5°, and 15^{m}x2°5. The largest scale results are given in Tables 3-8. Each of these has been examined for trends and then the intermediate resolution tables studied in an attempt to more clearly delineate any systematic right ascension or declination dependencies that might be present. The highest resolution grids merely prove that our computer can generate more numbers (3456 per systematic difference) than we can simultaneously absorb. Some brief comments on each Table follow.

Table 3: There are definite 12^{h} and 24^{h} right ascension trends, no apparent declination variation, and a noticeable minimum near 8^{h},50°. The standard deviation about the mean is typically 20-30 units ($0^{s}.001$).

Table 4: Again 12^{h} and 24^{h} right ascension variations with a noticeable ridge at $\delta = 85°$. Standard deviations are 35-45 units (0".01).

Table 5: Fairly flat except for the $\delta = 55°$ minimum. Standard deviations of 20-30 units (0".01).

Table 6: The proper motion tables all show much more variation than do the positional tables and this is reflected in large standard deviations, here 65-75 units ($0\rlap{.}''001$/cent). In addition to what may be 12^h and 24^h periodicities, several local extremes are present (8^h, 55°; 8^h, 80°).

Table 7: Very noisy with a δ=85° maximum and minima at δ=25°, 55°. Standard deviations are 100-110 units ($0\rlap{.}''01$/cent).

Table 8: Fairly smooth but large in value (unit = $0\rlap{.}''1$/cent) with standard deviations $\sim$60 units. There's a minimum at δ=55°.

TABLE 3

VALUES OF $\Delta\alpha\cos\delta$ $0^{s}.001$

$\delta \backslash \alpha$	$0^h.5$	$1^h.5$	$2^h.5$	$3^h.5$	$4^h.5$	$5^h.5$	$6^h.5$	$7^h.5$	$8^h.5$	$9^h.5$	$10^h.5$	$11^h.5$	$12^h.5$	$13^h.5$	$14^h.5$	$15^h.5$	$16^h.5$	$17^h.5$	$18^h.5$	$19^h.5$	$20^h.5$	$21^h.5$	$22^h.5$	$23^h.5$
85°	-9	11	14	-2	-1	-6	-3	7	-1	-6	-8	-2	3	4	5	-3	-7	-2	-1	2	-2	1	2	3
75°	-5	-4	-3	-3	-2	-7	-6	-2	-2	4	1	-7	-4	4	3	2	-4	4	2	0	-8	-11	-11	-4
65°	7	8	10	7	7	4	1	-4	6	3	8	11	1	9	10	9	4	5	11	1	5	5	9	11
55°	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-2
45°	0	-1	0	-7	-5	-10	-10	-15	-10	-4	2	1	-2	-2	-5	-4	-6	4	6	3	1	-2	-1	-6
35°	9	3	6	-2	-4	-6	1	3	-5	-2	3	6	-5	-6	-4	1	-5	-5	-1	2	1	5	8	7
25°	2	2	2	2	3	6	2	-2	-6	-5	1	3	4	0	-4	0	-9	-9	-8	-3	-2	5	7	4
15°	-8	-11	2	-6	-6	-1	-5	-5	-7	-3	-5	0	-1	-5	-5	-6	-3	-6	-2	-4	-7	-1	-9	-7
5°	-3	-1	0	-2	11	5	7	11	10	16	6	3	0	0	-3	0	6	5	3	7	8	2	1	0

TABLE 4

VALUES OF $\Delta\delta$ IN $0''.01$

$\delta \backslash \alpha$	$0^h.5$	$1^h.5$	$2^h.5$	$3^h.5$	$4^h.5$	$5^h.5$	$6^h.5$	$7^h.5$	$8^h.5$	$9^h.5$	$10^h.5$	$11^h.5$	$12^h.5$	$13^h.5$	$14^h.5$	$15^h.5$	$16^h.5$	$17^h.5$	$18^h.5$	$19^h.5$	$20^h.5$	$21^h.5$	$22^h.5$	$23^h.5$
85°	15	18	2	12	24	16	30	19	16	14	28	37	25	35	37	32	15	21	27	40	41	45	35	30
75°	-3	4	9	17	16	7	15	4	14	13	16	26	20	22	21	8	-2	-3	-7	-8	6	6	16	5
65°	-8	-4	9	16	6	8	15	-6	1	3	0	5	9	22	9	5	0	8	-5	1	-11	2	13	0
55°	-1	0	2	16	6	-2	6	0	-1	4	-4	-2	3	-1	-4	0	12	6	-5	-8	-3	2	3	-5
45°	20	24	17	10	2	9	5	-9	-7	1	-4	-2	1	-8	-9	8	0	1	1	3	2	6	-12	-5
35°	3	16	17	1	1	7	11	-6	5	5	0	1	1	1	-3	15	14	7	12	16	-3	-2	-9	-9
25°	1	9	-5	-9	-8	-11	-1	-4	-8	-6	-16	-3	-4	1	5	4	17	7	5	5	-1	-3	-9	-10
15°	4	1	0	3	9	0	2	12	7	8	6	5	5	1	3	2	11	5	8	6	7	-2	11	-3
5°	14	2	11	2	-3	13	4	16	5	11	5	4	12	9	1	3	3	3	2	-8	0	1	6	6

TABLE 5

VALUES OF $\Delta p = [(\Delta\alpha\cos\delta)^2+(\Delta\delta)^2]^{1/2}$ IN 0".01

δ\α	$0^h.5$	$1^h.5$	$2^h.5$	$3^h.5$	$4^h.5$	$5^h.5$	$6^h.5$	$7^h.5$	$8^h.5$	$9^h.5$	$10^h.5$	$11^h.5$	$12^h.5$	$13^h.5$	$14^h.5$	$15^h.5$	$16^h.5$	$17^h.5$	$18^h.5$	$19^h.5$	$20^h.5$	$21^h.5$	$22^h.5$	$23^h.5$
85°	41	44	43	43	46	42	53	50	44	44	55	58	54	56	56	50	40	48	53	54	54	60	53	49
75°	54	57	55	51	50	48	48	49	48	57	54	57	50	53	47	51	49	53	48	44	53	57	61	52
65°	53	54	55	54	57	54	53	48	48	48	47	51	49	53	49	52	51	53	53	44	52	51	[illegible]	55
55°	34	[illegible]	[illegible]	[illegible]	29	32	36	[illegible]	36	[illegible]	[illegible]	[illegible]	[illegible]	32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29	[illegible]	29
45°	60	60	57	55	54	55	56	59	54	54	51	48	51	52	54	51	51	53	57	54	55	57	56	57
35°	50	51	53	49	45	45	46	45	48	47	46	46	46	51	49	54	49	42	46	47	43	45	49	48
25°	46	49	49	43	43	47	46	46	42	43	47	45	44	44	43	45	49	48	47	45	45	43	43	44
15°	45	46	40	44	44	42	40	41	41	40	40	45	44	44	47	44	43	47	41	44	45	42	44	42
5°	45	49	48	43	53	48	51	53	50	54	48	49	49	47	45	43	47	46	43	48	46	45	43	45

TABLE 6

VALUES OF $\Delta\mu_\alpha \cos\delta$ IN $0^s.001$/CENT

$\delta \backslash \alpha$	$0^h.5$	$1^h.5$	$2^h.5$	$3^h.5$	$4^h.5$	$5^h.5$	$6^h.5$	$7^h.5$	$8^h.5$	$9^h.5$	$10^h.5$	$11^h.5$	$12^h.5$	$13^h.5$	$14^h.5$	$15^h.5$	$16^h.5$	$17^h.5$	$18^h.5$	$19^h.5$	$20^h.5$	$21^h.5$	$22^h.5$	$23^h.5$
85°	-11	36	42	19	27	5	9	43	25	20	12	32	32	44	33	9	-2	7	5	1	-22	-10	-8	0
75°	12	-2	0	11	-3	-5	-8	19	16	14	9	13	2	21	11	2	-7	20	8	6	-19	-21	-15	-4
65°	10	15	28	28	6	12	22	-2	24	26	28	31	0	18	26	28	-3	9	20	-13	5	-3	11	14
55°	-10	-10	-1	-1	-22	-19	-28	-44	-49	-27	4	24	-6	17	-13	-19	-25	-30	-36	-40	-26	-29	-8	-15
45°	-1	-6	6	-13	-11	-19	-12	-19	-12	-6	14	9	7	-1	-9	-1	-9	6	11	-2	-2	-6	-1	-4
35°	14	7	16	7	-4	-20	7	13	-10	4	9	13	-9	-16	-6	2	-10	-10	-3	-2	2	8	14	9
25°	-1	2	12	3	6	4	-1	-4	-21	-16	-3	17	-7	-10	-8	-2	-30	-26	-12	-5	-1	7	10	27
15°	-8	-15	6	8	1	3	1	-22	-9	-3	8	3	-1	-3	-16	-36	-40	-20	-3	-16	-20	1	-11	-12
5°	-1	3	0	11	5	5	15	16	12	20	28	21	2	-2	-6	-18	3	-1	1	5	23	19	16	12

TABLE 7

VALUES OF $\Delta\mu_\delta$ IN $0''.01$/CENT

$\delta\backslash\alpha$	$0^h.5$	$1^h.5$	$2^h.5$	$3^h.5$	$4^h.5$	$5^h.5$	$6^h.5$	$7^h.5$	$8^h.5$	$9^h.5$	$10^h.5$	$11^h.5$	$12^h.5$	$13^h.5$	$14^h.5$	$15^h.5$	$16^h.5$	$17^h.5$	$18^h.5$	$19^h.5$	$20^h.5$	$21^h.5$	$22^h.5$	$23^h.5$
85°	39	51	21	45	65	66	66	53	41	31	66	87	69	66	62	56	16	31	48	70	81	87	85	45
75°	-6	19	13	18	16	12	26	7	15	23	21	44	48	27	40	19	-13	-6	-22	-31	3	7	19	2
65°	-19	-16	6	30	13	37	29	-12	10	9	6	9	12	40	21	37	4	4	-17	-10	-36	-10	17	-12
55°	6	-26	-30	14	-9	5	-10	-49	10	-21	-47	-34	-39	9	-43	-14	-36	-12	-37	-44	-24	-26	21	-14
45°	28	39	39	19	-5	8	7	-21	-23	3	-12	-5	3	-17	-29	16	-8	-11	-5	-6	-8	8	-29	-11
35°	2	37	19	4	3	14	14	-30	-2	8	-5	-3	-4	-8	-14	28	32	2	18	35	-15	-7	-20	-29
25°	-7	32	-17	-34	-56	-17	-18	-9	-27	-26	-65	-20	-21	-11	1	31	54	-1	-1	12	-23	-8	-20	-45
15°	13	0	27	1	-4	0	-19	9	16	18	-22	5	21	26	21	34	16	21	19	36	7	4	23	19
5°	3	-5	-2	-11	-11	2	24	18	15	-3	-19	3	-1	11	24	22	5	-8	-11	-22	-23	-10	17	-3

TABLE 8

VALUES OF $\Delta\mu = [(\Delta\mu_\alpha \cos\delta)^2 + (\Delta\mu_\delta)^2]^{1/2}$ IN $0\rlap{.}''1$ CENT

$\delta\backslash\alpha$	$0^h\!.5$	$1^h\!.5$	$2^h\!.5$	$3^h\!.5$	$4^h\!.5$	$5^h\!.5$	$6^h\!.5$	$7^h\!.5$	$8^h\!.5$	$9^h\!.5$	$10^h\!.5$	$11^h\!.5$	$12^h\!.5$	$13^h\!.5$	$14^h\!.5$	$15^h\!.5$	$16^h\!.5$	$17^h\!.5$	$18^h\!.5$	$19^h\!.5$	$20^h\!.5$	$21^h\!.5$	$22^h\!.5$	$23^h\!.5$
85°	13	14	14	14	14	14	14	15	14	14	15	15	13	14	14	14	14	13	15	13	15	15	15	14
75°	15	15	15	14	15	15	14	15	15	15	15	14	14	15	15	15	14	15	15	14	15	15	15	15
65°	14	14	14	15	15	15	15	14	14	15	15	15	15	15	15	15	15	15	15	14	15	14	15	15
55°	13	13	12	13	13	13	13	15	14	13	13	13	12	13	13	13	12	13	14	14	13	13	13	12
45°	15	16	15	15	14	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	16	15
35°	15	15	15	16	15	15	15	14	15	15	15	14	14	15	15	15	15	14	15	15	14	15	15	15
25°	14	14	13	14	14	14	14	14	13	14	14	14	13	14	13	14	15	14	15	14	15	13	14	15
15°	14	14	14	14	14	13	13	14	14	13	14	13	14	13	14	14	14	14	14	15	14	14	14	14
5°	14	14	15	14	14	14	15	14	15	14	15	14	14	14	15	14	14	14	14	14	14	15	15	15

V. MAGNITUDE AND COLOR EFFECTS

As the dimensionality of the parameter space increases it becomes increasingly difficult to absorb all of the information one can generate. Hence the analysis presented in this Section is all position independent. The full dependence of (say) $\Delta\alpha\cos\delta$ on α, δ, m, and c will be derived in Part II. Again, as some of our readers may not see, a priori, the importance of apparent magnitude or color index effects, a little bit of background is appropriate. Magnitude effects arise in visual determinations of right ascension because of the nature of the observing technique and psychological effects in the observer. One uses an instrument constrained to the plane of the celestial meridian (a transit circle or meridian instrument) and the rotation of the Earth carries the star across the telescope's field-of-view. Thus the instant of meridian passage is the key event and is usually fixed by watching the star traverse the central wire of a grid in the reticle. However, human beings typically judge bright stars to have transited early and faint stars to have transited late. These systematic effects are of the order of $0\overset{s}{.}01$/mag. Declinations should be (and usually are) unaffected.

Color index corrections arise from another source. The image of a star formed by the atmosphere is not a point or even circular but, rather, a spectrum with the blue end up.

The spread increases with zenith distance going from 0" to $2''.2$ as z increases from 0° to 75° (red to blue-green separation). Thus, an obviously red or blue star's zenith distance will systematically vary due to this differential refraction. This in turn changes both the right ascension and declination one deduces. Note that this will occur even if care is taken to use a wavelength dependent index of refraction.

To (crudely) search for obvious apparent magnitude or color index effects the analysis of Section III has been repeated except for different brightness and temperature groups. Table 9 lists the m and c distributions for those stars in common to the catalogs with matching BD numbers. For those stars north of the equator with $\Delta p \leq 2''.5$ and matching BD numbers, the following 5 (4) apparent magnitude (color index) groups have been used: $8^m.0 \leq m < 9^m.0$, $9^m.0 \leq m < 9^m.5$, $9^m.5 \leq m < 10^m.0$, $10^m.0 \leq m < 10^m.5$, and $10^m.5 \leq m < 11^m.5$ ($-0^m.5 \leq c < 0^m.5$, $0^m.5 \leq c < 1^m.0$, $1^m.0 \leq c < 1^m.5$, and $1^m.5 \leq c < 2^m.5$). These contain 25,736, 23,247, 25,576, 20,800, and 15,429 (19,821, 24,233, 21,746, and 12,069) stars. Tables 10 and 11 list the mean value of each difference in each apparent magnitude and color index bin as well as their values for the entire sample. Moreover this has been done for $\Delta p \leq 2''.5$ and $\Delta p \leq 1''.25$ separately ($\delta \geq 0°$ and matching BD numbers in all instances). One thing we can see is that $\Delta\delta$ is positive in all m and c bins. This shows up in other areas too and shows that

TABLE 9

APPARENT MAGNITUDE AND COLOR INDEX DISTRIBUTION

Magnitude Range	Number*	Color Index	Number+
$5^m.0$: $5^m.5$	309	$-3^m.0$: $-2^m.5$	0
5.5 : 6.0	572	-2.5 : -2.0	1
6.0 : 6.5	1036	-2.0 : -1.5	1
6.5 : 7.0	1412	-1.5 : -1.0	16
7.0 : 7.5	3062	-1.0 : -0.5	396
7.5 : 8.0	5648	-0.5 : 0.0	4032
8.0 : 8.5	10005	0.0 : 0.5	15789
8.5 : 9.0	15731	0.5 : 1.0	24233
9.0 : 9.5	23247	1.0 : 1.5	21746
9.5 : 10.0	25576	1.5 : 2.0	9724
10.0 : 10.5	20800	2.0 : 2.5	2345
10.5 : 11.0	11486	2.5 : 3.0	358
11.0 : 11.5	3943		
11.5 : 12.0	1097		
12.0 : 12.5	262		
12.5 : 13.0	18		

*The total number is 124,485 of which 281 are brighter than $5^m.0$.

+The total number is 78,657 of which 16 are redder than $3^m.0$.

the preponderance of positive values for $\Delta\delta$ is both real and widespread. The second point is, in Table 10, any trend that's present is independent of the Δp limit. Furthermore the value of $\Delta\mu/\Delta p$ is as would have been predicted for $\Delta p \leq 1''.25$ but not quite (it's too large) for $\Delta p \leq 2''.5$. Since the sample values of Δp haven't changed significantly there can't be a large fraction of stars with $\Delta p \in (1''.25, 2''.5]$ which are mis-identified. The latter statements hold for Table 11 but the former may not. Remembering how inhomogeneous the SAOC m_V values are, if one ignores the bluest and reddest stars, then there are probably no trends in Table 11. Finer resolution studies don't change this picture. (The bin sizes for both m and c were chosen to have roughly comparable numbers of stars.)

TABLE 10

THE MAGNITUDE EFFECT

m Range	$\Delta\alpha\cos\delta$	$\Delta\delta$	Δp	$\Delta\mu_\alpha\cos\delta$	$\Delta\mu_\delta$	$\Delta\mu$
	(0".001)			(0".001/cent)		
$\Delta p \leq 1''.25$						
$8^m.0:\ 9^m.0$	23	37	435	11	8	796
9.0: 9.5	4	39	420	-22	12	797
9.5:10.0	-8	32	431	-17	-3	794
10.0:10.5	-18	36	443	-41	-11	803
10.5:11.5	-2	53	482	-29	-6	807
$\Delta p \leq 2''.5$						
$8^m.0:\ 9^m.0$	25	38	457	22	42	1395
9.0: 9.5	4	40	430	-23	25	1407
9.5:10.0	-10	35	444	-33	-16	1422
10.0:10.5	-17	40	459	-66	-19	1438
10.5:11.5	-2	57	509	-39	2	1468
All	3	40	465	3	33	1415

TABLE 11

THE COLOR EFFECT

c Range	$\Delta\alpha\cos\delta$	$\Delta\delta$	Δp	$\Delta\mu_\alpha\cos\delta$	$\Delta\mu_\delta$	$\Delta\mu$
$\Delta p \leq 1''.25$		(0".001)			(0".001/cent)	
$-0^m.5:0^m.5$	8	30	428	-16	4	798
0.5:1.0	-2	23	427	-44	-24	795
1.0:1.5	-4	37	438	-24	-23	796
1.5:2.5	13	77	478	-15	3	815
$\Delta p \leq 2''.5$						
$-0^m.5:0^m.5$	8	31	437	-32	12	1416
0.5:1.0	-2	25	440	-61	-51	1416
1.0:1.5	-5	39	454	-39	-36	1438
1.5:2.5	12	82	499	15	11	1467
All	3	40	465	3	33	1415

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systematic differences

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discusses the systematic differences, in position and proper motion, between the SAOC and the AGK3. Stars in common to both catalogs, with matching BD numbers, and a positional (proper motion) difference of at most 2".5 (2".5/cent) provide the raw data. There are 128,631 (89,709) such stars north of $-2^\circ.5$. The systematic differences have also been examined for dependence on apparent magnitude and color index. The mean and standard deviations in the total positional (proper motion) difference between the two catalogs are 0".47 and 0".30 (1".42/cent and 0".61/cent). Approximately 1% of the stars have a positional difference in excess of 10". Finally, there is a definite excess of positive values of $\Delta\delta$; for the 127,637 matches with $|\Delta\alpha\cos\delta| \leq 1''.25$ the mean value of $\Delta\alpha\cos\delta$ is 0".007 and for the 128,084 matches with $|\Delta\delta| \leq 1''.25$ the mean value of $\Delta\delta$ is 0".041.